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Evaluation of Housing Unit Field Operations and Instruments for the Accuracy and Coverage Evaluation

FINAL REPORT

This evaluation study reports the results of research and analysis undertaken by the U.S. Census Bureau. It is part of a broad program, the Census 2000 Testing, Experimentation, and Evaluation (TXE) Program, designed to assess Census 2000 and to inform 2010 Census planning. Findings from the Census 2000 TXE Program reports are integrated into topic reports that provide context and background for broader interpretation of results.

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U S C E N S U S B U R E A U

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EXECUTIVE SUMMARY

This report evaluates specific field operations and instruments used during the Housing Unit Phase of the Accuracy and Coverage Evaluation. The Housing Unit Phase measured the Census 2000 housing unit coverage.

The 2000 Accuracy and Coverage Evaluation was a survey conducted independently of the Census 2000 in a nationwide sample of block clusters to measure both the rate of the census coverage and the rate of erroneous enumeration. Throughout the Accuracy and Coverage Evaluation survey operations, quality assurance measures were in place to check all field operations to ensure that the highest quality work was being produced.

To determine how well the field operations performed and to identify where improvements may be beneficial, we focused on results from the following housing unit operations:

- Address Listing operation: August 1999 - December 1999
  The Address Listing operation was an independent listing of addresses for housing units in the Accuracy and Coverage Evaluation sample block clusters.

- Initial Housing Unit Followup operation: February 2000 - April 2000
  The Initial Housing Unit Followup operation occurred to obtain additional information on housing units that could not be matched to a census address during the Initial Housing Unit Matching operation.

- Relisting operation: April 2000 - May 2000
  The Relisting operation revisited housing units and conducted a new listing operation in clusters that the original lister had listed in the wrong block.

- Targeted Extended Search 2 operation: January 2001 - April 2001
  The second Targeted Extended Search operation was performed to ascertain whether some of the housing units that the Accuracy and Coverage Evaluation determined to be erroneous enumerations (not existing on Census Day) were actually geocoding errors (existing as housing units outside the cluster.)

- Final Housing Unit Followup: March 2001 - May 2001
  The Final Housing Unit Followup operation was similar to the Initial Housing Unit Followup operation. Housing units that were added to or deleted from the inventory of housing units since the Initial Housing Unit operation were processed and the results were then used for housing unit estimation.

The instruments evaluated were the paper questionnaires used during the:

- Initial Housing Unit Followup operation and,
- Final Housing Unit Followup operation.

Our evaluation used unweighted data and answered the following questions.

How well did the Accuracy and Coverage Evaluation listing operation locate the housing units in the sample blocks?

The Address Listing operation was an independent listing of addresses for housing units in the Accuracy and Coverage Evaluation sample block clusters. During the period between August 1999 and December 1999, Accuracy and Coverage Evaluation listers canvassed neighborhoods and recorded in Independent Listing Books the addresses of all the housing units in the sample block clusters. This type of independent listing was a difficult and error-prone task that required checking and verification. Therefore, we designed an extensive quality assurance program which involved five different quality control checks. Failure in any of those checks caused the particular sample cluster to be sent back to the field for a 100 percent dependent quality control review. Although almost half (49.3 percent) of the clusters failed one or more of the five quality control checks, only 18.9 percent of the clusters had changes (added or deleted addresses) resulting from the quality control process.

The after followup matching results from the Initial Housing Unit operation were also used as indicators of the quality of the listing operation. Matching results indicate that about 5 percent of the housing units were erroneously listed and less than 4 percent of the addresses were missed during Address Listing. Address Listing was less error prone in mailout/mailback areas than in update/leave areas. Mailout/Mailback areas had 4.6 percent errors of inclusion and 3.8 percent errors of omission, while percents for update/leave areas were 7.0 percent and 4.2 percent, respectively.

How effective was the relisting operation in identifying the Accuracy and Coverage Evaluation housing units?

As a result of the Relisting operation, we were able to match about 88.3 percent of the housing units in the relist clusters to the census inventory. Without this operation, none of the housing units would have matched.

What effect did the wording of the match and duplicate questions on the Initial Housing Unit Followup questionnaire have on the interview? Did the rewording of the questions on the Final Housing Unit Followup questionnaire improve the interviewers' understanding of the duplication and match questions?

The match and duplicate questions required the listers to identify if there were any other

addresses listed in the reference list that could be considered duplicates or additional matches to the addresses being followed-up. The reference list included all the Accuracy and Coverage Evaluation addresses as well as the Census addresses in the block clusters. During the Initial Housing Unit Followup operation, interviewers had difficulty answering those questions on the Initial Housing Unit Followup questionnaire. Often they listed the same unit they were following up as a match or duplicate. Changes were made to these questions to help the interviewer's understanding of the duplicate and match questions for the Final Housing Unit operation. There was a substantial decrease in the percentage of questionnaires with incorrect answers in the duplicate questions during the Final Housing Unit Followup (0.6 percent) than during the Initial Housing Unit Followup (14.2 percent). The decrease in the error rate was not as great for the match questions (from 0.8 percent in the initial phase to 0.2 percent in the final phase).

Were any erroneous enumerations in the Initial Housing Unit Matching identified as geocoding errors in the second Targeted Extended Search operation?

Yes, there is evidence that some addresses classified as erroneous enumerations in the Initial Housing Unit Matching were actually geocoding errors. A sample of census units coded as erroneous enumerations in the Initial Housing Unit Matching operation were sent to a second Targeted Extended Search operation. Results show that 8.2 percent of the sample (443 housing units out of 5,364 erroneous enumerations in sample) were geocoding errors. Of the 443 housing units in sample, 6.3 percent were found in the first ring of surrounding blocks and 1.9 percent were found beyond the ring of surrounding blocks.

Was the Initial Housing Unit Followup operation successful at identifying which addresses, unresolved after the initial matching, should be part of the Preliminary Enhanced List for Person Interviewing?

Of the 838,427 Accuracy and Coverage Evaluation sample addresses and 859,296 census addresses in the same sample blocks, 358,741 addresses went to followup. These were Accuracy and Coverage Evaluation addresses that could not be matched to census addresses, census addresses that could not be matched to Accuracy and Coverage Evaluation addresses, matched addresses that were possible duplicates and Accuracy and Coverage Evaluation matches with an undetermined unit status such as new construction, future construction, unfit for inhabitation, vacant trailer site, and so forth.

Overall, 59.5 percent of the housing units that went to followup were placed on the Preliminary Enhanced List. Both confirmed (59.0 percent) and unresolved (0.6 percent) addresses were placed on the Preliminary Enhanced List.

Although slightly more census addresses went to followup, the Housing Unit Followup rate was much higher for Accuracy and Coverage Evaluation addresses. Of the Accuracy and Coverage Evaluation addresses that went to followup, 76.3 percent were placed on the Preliminary Enhanced List compared to 44.7 percent of the census addresses that went to followup.

Conclusions/Recommendations

The housing unit field operations and instruments evaluated in this paper for the Accuracy and Coverage Evaluation were appropriate in measuring coverage of housing units. We make the following recommendations:

- Address Listing operation

  The Address Listing operation was an independent listing of addresses for housing units in the Accuracy and Coverage Evaluation sample block clusters. This type of independent listing is very difficult and error prone task. The quality assurance process for Address Listing worked effectively to identify, prevent and correct errors as necessary. The field rework resulting from the quality assurance checks resulted in improved listing of 18.9 percent of the clusters. Therefore, we recommend continuing the quality assurance process on Address Listing.

  Less than one percent of the clusters in the Accuracy and Coverage Evaluation (62 clusters out of 11,303) had to be relisted. As a result of the Relisting operation, we were able to match about 88.3 percent of the housing units in the relist clusters to the census inventory. Therefore, we recommend that relisting continue to be part of future coverage measurement operations.

- Initial Housing Unit Followup operation

  The Initial Housing Unit Followup operation confirmed that more than half of the addresses that went to followup (59.0 percent) existed as housing units and were placed on the Preliminary Enhanced List. Also, using final matching results from the Initial Housing Unit operation we estimated that about 5 percent of the housing units were erroneously listed and less than 4 percent of the addresses were missed during Address Listing. We recommend that housing unit matching and followup continue to be part of future coverage measurement operations.

  The second Targeted Extended Search operation provided evidence that there were some housing units classified as erroneous enumerations that were actually geocoding errors. We recommend that we build the second Targeted Extended Search operation into the Initial Housing Unit Followup operation to minimize misclassification of geocoding errors as erroneous enumerations.

- Followup Questionnaire

  Results from comparisons of Initial and Final Housing Unit Followup interviewer response patterns verified suspicions that some questions were not being understood by the interviewers during the initial phase. We recommend that for future applications we give as much testing attention to the interviewer's instruments as we do to the instruments used by respondents, in particular, we should conduct cognitive testing on future followup instruments.

1. BACKGROUND

The Census Bureau conducted an Accuracy and Coverage Evaluation (A.C.E.) to measure the overall and differential coverage of the U.S. population in Census 2000. The A.C.E. was a study conducted independently of the Census 2000 and it measured both the rate of the census undercount and the rate of erroneous enumeration.

The A.C.E. was conducted in two phases: Housing Unit and Person. The Housing Unit phase measured housing unit coverage. There were two distinct parts for the Housing Unit phase: (1) the Initial Housing Unit operation was conducted to identify the housing units in the A.C.E. sample and (2) the Final Housing Unit operation was conducted to process changes to the census and the A.C.E. housing unit inventories after the Person phase. In this evaluation, we ascertained how well the field operations were carried out and determined the instruments' success in getting correct information. The evaluation attempts to identify where improvements may be beneficial.

In the Initial Housing Unit Phase, A.C.E. listers canvassed neighborhoods before Census Day and recorded in Independent Listing Books (ILBs)[1] addresses of all the housing units in the A.C.E. sample clusters. The results of the A.C.E. Independent Listing operation and the January 2000 update of the Decennial Master Address File (DMAF) were used in a matching operation. Addresses of housing units from the A.C.E. list were compared with the census inventory of housing units in A.C.E. areas to identify those housing units that were missed or duplicated. A housing unit followup operation was performed during February 2000 to verify the existence of housing units identified on the census inventory but missed in the A.C.E. listing, or identified in the A.C.E. listing but missing in the census inventory, and to verify the status of housing units classified as potential duplicates. After the matching and followup operations, some A.C.E. clusters which contained excessive amounts of erroneously listed housing units were determined to have been located outside of the cluster boundary (that is, all clusters were classified as housing unit geocoding errors.) These clusters were sent back to the regions to be relisted. The relisted ILBs were then compared to a list of the housing units determined to be geocoding errors from the original ILB to be sure these units were not erroneously included again. The results of the matching and followup operations and the relisting operation determined those housing units that were included on the Preliminary Enhanced List (that is, list of addresses confirmed to exist), which was used, after subsampling, for the A.C.E. person interview operation.

After the Initial Housing Unit Matching operation, the A.C.E. conducted the Person Phase operation. During this phase, a Targeted Extended Search (TES) in surrounding blocks was conducted for census housing units with addresses assigned to the incorrect block (geocoding error.) The results were used to update the A.C.E. inventory of housing units.[2]

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[1] For more details, see Corby, 1999.

[2] For more details, see Wolfgang, 2002.

Before the Final Housing Unit operations began, a second Targeted Extended Search (TES2) operation was performed to determine if the census addresses that were identified as erroneous enumerations (meaning they did not exist) in previous operations should have been identified instead as geocoding errors. This was intended to prevent classification of housing units that were not located in an interviewer's assigned cluster as nonexistent, when in fact the housing units could have existed, but outside the cluster.

The Final Housing Unit operation was conducted to process the updates to the census and A.C.E. housing unit inventories that occurred since the initial A.C.E. listing. The Final Housing Unit Matching operation processed DMAF records that were not on the Hundred-Percent Census Unedited File (HCUF) (deletes) and HCUF records that were not on the DMAF (adds), address corrections and other updates. In the Final Housing Unit Followup operation, we conducted followup interviews on the added census and A.C.E. housing units.[3]

Throughout the A.C.E., there were quality assurance measures in place to check all field operations to ensure the highest quality work.

This evaluation focuses on results from the Address Listing operation, the Initial Housing Unit Followup operation, the TES2 operation, the Relisting operation and the Final Housing Unit Followup operations to ascertain how well the field operations were carried out and instruments' success in getting correct information. The evaluation also attempts to identify where improvements may be beneficial.

2. METHODS

2.1 Address Listing Operation

Results from the Address Listing Quality Assurance operation and the Initial Housing Unit (HU) Clerical Matching operation were examined to help determine how well the Address Listing operation listed addresses in the A.C.E. sample blocks. This type of independent listing is a difficult and error-prone task that requires checking and verification.

[3] For more details, see Childers, 2001.

2.1.1 Address Listing Quality Assurance Operation

We calculated the percent failure rate from the Address Listing Quality Assurance (QA) operation to determine the baseline quality indicators for the address listing. The percent failure rate is the number of QA checks that failed, out of the number of QA checks performed.

During the listing operation, five QA checks were conducted for each ILB completed for a cluster. An ILB failing any of these checks went back out to the field for a 100 percent review. The QA checker reviewed and confirmed each item listed in the ILB. The results of each QA check were recorded on the ILB's cover.[4] The QA checks were:

- HU count comparison. This check looked for clusters that had a different number of addresses than were contained in the DMAF. The assumption was that this test would fail if a lister listed in the wrong block. There was an override feature in cases where the regional office staff knew that the census counts were incorrect because of high growth in the area.

- Office edit. Each ILB was checked for completeness and accuracy of the basic street address of each housing unit, adherence to question skip sequence, completion of the number of units verification, street name consistency, and street name length.

- Respondent check. A lister was instructed to talk with a respondent of the housing unit to verify its status. A sample of respondents was contacted to verify that the lister's contacts actually occurred.

- Address range check. This check used Street Index software to verify that at least one of the house numbers listed in the block was within the range of valid house numbers provided by the software for that block. This check was only applicable for city style addresses.

- Percent by observation. The percent of listings conducted by observation was calculated for each ILB. The goal of this check was to ensure that the interviewers attempted to contact knowledgeable respondents to aid in identifying housing units (such as garage apartments) that were not apparent from the street. This check failed if more than 20 percent of the cluster was done by observation.

The possible results for each check were pass, fail, not applicable and supervisory override. The last two were options for the QA supervisor in special circumstances and were not considered either "pass" or "fail."

[4] For more details, see Byrne, 2001.

2.1.2 Initial Housing Unit Matching Operation

The HU computer matching operation compared the ILB file to the DMAF and coded records as matches, possible matches, or nonmatches (that is, either A.C.E. or census nonmatched addresses.) After the computer matching, clerical matching was done to resolve any computer nonmatched records and paired addresses that were classified as possible matches. Records which still remained "nonmatches" and "possible matches" after clerical matching were sent to Initial Housing Unit Followup along with those records believed to be A.C.E. or census duplicates.

During followup, an interviewer determined if the address actually existed as a housing unit in the cluster. After the field followup, there was another round of clerical matching to code the results of the followup interview.

The after followup matching results were used as another indicator of the quality of the listing operation. The percentage of A.C.E. housing units erroneously included in the listing (such as duplicates or geocoding errors), as well as the percentage of A.C.E. housing units erroneously excluded from the listing (such as units confirmed to exist in the cluster that were present on the census inventory but missed by the A.C.E. listing - census nonmatches) were calculated.

We referred to the first situation as errors of inclusion and the second as errors of omission. Following are the formulas for errors of inclusion and errors of omission.

$$\text{A.C.E. addresses erroneously included in the listing (Errors of Inclusion)} = \frac{\text{Sum of A.C.E. duplicates, geocoding errors, address deletes, and map spot deletes}}{\text{Total listed A.C.E. HUs}}$$

$$\text{Addresses omitted from the A.C.E. listing (Errors of Omission)} = \frac{\text{Sum of HUs confirmed to exist in the census but not in the A.C.E. (Census nonmatches)}}{\text{A.C.E. HUs confirmed to exist plus census HUs confirmed to exist but not matched to the A.C.E.}}$$

Refer to Appendices A and B for more details about the formulas.

See Section 4.1.2 for results.

2.2 Initial Housing Unit Followup (HUFU) Operation

As an indicator of how well A.C.E. listing and census operations did in properly identifying housing units, we examined the results of the Initial Housing Unit Followup operation. In

particular, we examined the rate at which addresses that went to followup were either confirmed or unresolved.

The results of the After Followup Matching operation determined which housing units were placed on the Preliminary Enhanced List. The A.C.E. and census housing units confirmed to exist and those remaining unresolved after the followup matching operation were placed on the Preliminary Enhanced List and included, after subsampling, in the Person phase of the A.C.E.

We calculated the HUFU rate using the following formula:

$$\text{HUFU Rate} = \frac{\text{A.C.E. and census addresses confirmed to exist as HUs and unresolved addresses}}{\text{Total number of addresses that went to HUFU}}$$

Refer to Appendices A and B for more details about the formulas.

See Section 4.2 for results.

2.3 Relisting Operation

Relisting occurred because the results of the Initial Housing Unit matching indicated geocoding errors when the original lister listed a cluster in the wrong block. When more than 80 percent of the cluster had geocoding errors, the cluster was selected for relisting. Field interviewers used a blank ILB to record housing unit information in the correct sample block clusters. The exact QA process as described for the initial listing was conducted for the relisted clusters. However, these relisted clusters did not go through the Initial Housing Unit Matching and followup operations because those operations were completed. Instead, the relisted clusters did go through the Final Housing Unit Matching and Followup operations.[5]

We calculated how effective the relisting operation was in identifying A.C.E. housing units that matched to census housing units. We used the following formula:

$$\text{Relist Match Rate} = \frac{\text{Number of A.C.E. Relisted HUs matched to the census}}{\text{Total A.C.E. units confirmed to exist in relisted clusters}}$$

Refer to Appendices A and B for more details about the formulas.

See Section 4.3 for results.

[5] For more details, see Smith and Byrne, 2001.

2.4 Geocoding Errors in Targeted Extended Search 2 (TES2) Operation

A sample of clusters containing at least one housing unit coded as an erroneous enumeration during the Initial Housing Unit phase was eligible to be selected for TES2. Census addresses coded as not existing as a housing unit (that is nonresidential or nonexistent on Census Day) within the cluster were classified as erroneous enumerations. Clusters with four or more cases coded as erroneous enumeration were in sample with certainty for TES2. There were concerns that some of these housing units existed outside the cluster and should have been coded as geocoding errors. Geocoding errors were treated differently than erroneous enumeration in estimation. To evaluate this, we calculated the percent of erroneous enumerations in sample for TES2 identified by the Initial Housing Unit matching that were later identified as geocoding errors in the TES2 operation.

See Section 4.4 for results.

2.5 Initial Housing Unit Followup (HUFU) and Final Housing Unit Followup (FHUFU) Questions

The followup forms used during the Initial and Final Housing Unit Followup operations contained questions that were not designed to be read to the respondents. The questions were intended to be used by the interviewers as a guide to verify information about the housing units. The match and duplicate questions required the listers to identify if there were any other addresses listed in the reference list that could be considered duplicates or additional matches to the addresses being followed-up. The reference list included all the A.C.E. addresses as well as the Census addresses in the block cluster. During the Initial Housing Unit Followup operation, interviewers had difficulty answering those questions on the Initial Housing Unit Followup questionnaire. Often they listed the same unit they were following up as a match or duplicate. Therefore, it was determined that clarification was needed for the duplicate and match questions on the Final Housing Unit Followup (FHUFU) form. The table that follows shows the duplicate and match questions as worded for the Initial HUFU operation and the questions as they were modified for the FHUFU operation.

Table M1. Initial Housing Unit Followup and Final Housing Unit Followup Questions

IHUFU Question	FHUFU Question	Changes
Duplicate Questions		
If the followup address was A.C.E.: Does (*A.C.E. address*) represent the same housing unit as any of the addresses listed in the **A.C.E. column** of the Housing Unit Reference List?	**If the followup address was A.C.E.:** Does (*A.C.E. address*) represent the same housing unit as any of the other addresses listed in the **A.C.E. column** of the Housing Unit Reference List *beside (address 1) and (address 2)*?*	The word "other" was added to the duplicate questions to clarify that we are looking for another address that is different from the address being followed-up.
If the followup address was Census: Does *(census address*) represent the same housing unit as any of the addresses listed in the **Census column** of the Housing Unit Reference List?	**If the followup address was Census:** Does (*census address*) represent the same housing unit as any of the other addresses listed in the **Census column** of the Housing Unit Reference List *besides (address 1) and (address 2)?**	Alternate wording that an interviewer was allowed to use was printed below the question box on those pages that had questions about duplicates.
Match Questions		
If the followup address was A.C.E.: Does (*A.C.E. address*) represent the same housing unit as any of the addresses listed in the **Census column** of the Housing Unit Reference List? **If the followup address was Census:** Does (census *address*) represent the same housing unit as any of the addresses listed in the **A.C.E. column** of the Housing Unit Reference List?	No change in the item wording of the specific questions.	Only alternate wording that an interviewer was allowed to use was printed below the question box on those pages that had questions about matches.

*This wording was added to the question where there were one or more duplicate addresses followed up.

For all cases where the match and duplicate questions were answered, we compared the entries of addresses from the Housing Unit Reference List to those printed at the top of the form. The Housing Unit Reference List was a compilation of A.C.E. addresses and census addresses in the cluster. Interviewers were to review this list to find additional (new) duplicates and/or matches to the followup address(es.) We calculated the frequency of enumerator errors that resulted from entering the same address in either of these questions for the Initial Housing Unit and Final Housing Unit operations. The results from both operations were compared.

See Section 4.5 for results.

3. LIMITS

This analysis is of the field operations and instruments used in the fifty states and the District of Columbia.

Measurement errors such as errors in data entry, coding and matching are beyond the scope of this project and report.

The TES2 operation was performed using TES forms. TES forms were designed to determine the location of the housing unit at the time of the interviewers' visit, not on Census Day, April 1, 2000.

Although wording changes were made to other questions on the FHUFU questionnaire, this report focuses on the responses made to the duplicate and match questions only (refer to Table M1, Initial Housing Unit Followup and Final Housing Unit Followup Questions in the Methods section.) These questions caused the most confusion and misunderstanding among the interviewers during HUFU.

4. RESULTS

4.1 Address Listing Operation

4.1.1 What are the baseline quality indicators for the A.C.E. listing operation?

Because of the importance of a complete and accurate A.C.E. address list, the Census Bureau devised a QA plan that would over-identify clusters with potential listing errors. If the cluster failed any QA checks, it was sent back to the field for an independent check of the listing books. This decision balanced the cost of extensive QA checks with the need for the best listing possible. The QA plan included multiple checks, which while likely correlated with incorrect listing, could not alone be considered the indicator of incorrect listing. For example, the housing unit count comparison check compared the number of A.C.E. units listed with counts obtained from the 1990 DMAF for the same block cluster. While the DMAF counts were updated throughout the decade, they were not the actual 2000 DMAF counts eventually used in the Initial Housing Unit Matching Operation. Therefore, differences in the counts could indicate real changes in the number of housing units, as well as errors by the lister such as listing the incorrect block. For this check, in either case, we felt a second field visit was beneficial.

Tables 1 and 2 show the results of the quality assurance checks for the A.C.E. listing.

There was a total of 11,303 clusters in the A.C.E. listing operation universe of which 91 were excluded from the QA evaluation because they were either relist clusters, or the data were missing or not applicable. The remaining 11,212 clusters were used to determine the rate of clusters failing the QA checks.

Some of the address listing QA checks were not applicable to each cluster. For example, because rural addresses are more likely to contain descriptions rather than house numbers, rural clusters were excluded from the "range" check which used commercial software to compare the house numbers listed in a block to the expected range of house numbers for that block. Therefore, not all clusters were subjected to all five QA checks. Additionally, some ILB's QA checks were not recorded at all because of keying errors. For our analysis, we used the keyed data to tally the number of checks a cluster failed divided by the number of checks performed for that cluster. The denominators could range from one check performed to five checks performed. To simplify the results, we collapsed these percentages into five categories of QA check failures, ranging from clusters failing none of the checks to clusters failing all checks performed. Percents may not sum precisely to 100 due to rounding error.

Table 1. Results of the QA checks on A.C.E. address listing

Number of checks failed out of number of checks performed	Percent Failed QA checks	Number of Clusters	Percent of Clusters
Failed zero (passed all)	$x = 0$	5,679	50.7
1 out of 5, 1 out of 4, or 1 out of 3	$0 < x < 0.4$	3,209	28.6
2 out of 5, 1 out of 2, 2 out of 4, or 3 out of 5	$0.4 \leq x \leq 0.6$	1,798	16.0
2 out of 3, 3 out of 4, or 4 out of 5	$0.6 < x < 1.0$	408	3.6
Failed all	$x = 1$	118	1.1

x = QA checks failed out of checks performed

Table 1, Results of the QA checks on A.C.E. address listing, shows the percent failure rate collapsed into the five categories. This table shows that:

- Over half (50.7 percent) of the clusters passed all of the QA checks.
- A small percentage (1.1 percent) of the clusters failed all of the QA checks.
- Overall, 49.3 percent of the clusters failed one or more of the QA checks performed.

Table 2. Results of the QA checks on A.C.E. address listing by Accuracy and Coverage Evaluation Regional Office (ACERO)

ACERO n = clusters	0% Zero failed	Percent Failed QA checks 0< x< 0.4 Failed one	0.4 ≤ x ≤ 0.6 Failed (1-3)	0.6< x< 1.0 Failed (2-4)	x =1 Failed all 5	Percent of total clusters failing one or more QA checks
Boston n=906	36.2	33.6	22.9	5.9	1.6	63.8
New York n=495	26.3	39.2	30.9	3.0	0.6	73.7
Philadelphia n=824	45.3	30.5	20.4	3.5	0.4	54.7
Detroit n=794	53.0	27.6	16.0	2.9	0.5	47.0
Chicago n=821	61.0	31.1	6.8	0.9	0.2	39.0
Kansas City n=954	53.0	32.1	12.2	2.5	0.2	47.0
Seattle n=937	54.6	26.7	14.1	3.3	1.3	45.4
Charlotte n=1033	49.0	29.1	16.8	4.2	1.0	51.0
Atlanta n=963	46.0	28.8	21.5	3.1	0.6	54.0
Dallas n=1105	44.9	26.8	19.0	6.2	3.2	55.1
Denver n=1534	58.9	25.4	10.3	4.6	0.8	41.1
Los Angeles n=846	66.1	19.7	10.8	1.7	1.8	34.0
Total percent of clusters	**50.7**	**28.6**	**16.0**	**3.6**	**1.1**	**49.3**

x = QA checks failed out of checks performed

Table 2, Results of the QA checks on A.C.E. address listing by Accuracy and Coverage Evaluation Regional Office (ACERO), shows the percentage of clusters that failed one or more QA checks by ACERO.

- Half of the ACEROs had over 50 percent of clusters that passed all QA checks.
- The Los Angeles ACERO had the lowest percentage (34.0 percent) of clusters that failed one or more QA checks among the ACEROs.
- Although the New York ACERO had the highest percentage (73.7 percent) of clusters failing QA, many of the clusters only failed one QA check.

Table 3. Changes made to address listing housing units by ACERO

ACERO	Number of clusters	Percent of total clusters failing one or more QA checks	Percent of total clusters with housing units added or deleted
Boston	906	63.8	27.9
New York	495	73.7	38.6
Philadelphia	824	54.7	19.7
Detroit	794	47.0	18.0
Chicago	821	39.0	12.9
Kansas City	954	47.0	14.2
Seattle	937	45.4	18.1
Charlotte	1,033	51.0	18.9
Atlanta	963	54.0	21.5
Dallas	1,105	55.1	18.4
Denver	1,534	41.1	16.6
Los Angeles	846	34.0	11.5
Total	**11,212**	**49.3**	**18.9**

Table 3, Changes made to address listing housing units by ACERO, shows the percent of clusters with housing units added or deleted due to the QA checks.

- Although 49.3 percent of the clusters listed failed one or more of the QA checks, only 18.9 percent of all clusters resulted in adding or deleting addresses during the Address Listing QA operation.

- Los Angeles had the lowest percent (11.5 percent) of units that were added or deleted to the listing and New York had the highest (38.6 percent.)

There was a relationship between the QA failure rate and the change rate for total clusters by ACERO. For example,

- The New York ACERO had the highest percent of clusters failing one or more QA checks (73.7 percent); it also had the highest percent (38.6 percent) of clusters that changed among the ACEROs.

- Los Angeles had the lowest percent for clusters that failed one or more QA checks (34.0 percent) as well as clusters that changed (11.5 percent.)

4.1.2 Based on the HU clerical matching results, how many A.C.E. addresses were errors of inclusion or errors of omission during Address Listing?

The after followup matching results from the Initial Housing Unit operation were used as indicators of the quality of the listing operation. A.C.E. housing units erroneously included in the listing (such as duplicates, A.C.E. address deletes or geocoding errors) were errors of inclusion. A.C.E. housing units erroneously omitted from the listing (such as units confirmed to

exist in the cluster that were present on the census inventory but missed by the A.C.E. listing (census nonmatches or geocoding errors) were errors of omission.

One of the reasons for errors of inclusion was including addresses of future construction. Since A.C.E. address listing occurred nine months before Census Day, listers were encouraged to include addresses in areas of future construction. By doing this, those addresses would be included in the Initial Housing Unit operation for matching (and placed on the list for Person Interviewing) if they were indeed completed (vacant or occupied) housing units on Census Day. Since the Initial Housing Unit followup operation was conducted closer to Census Day, it provided the opportunity to determine whether the address was for a completed housing unit (vacant or occupied) or not. If the address did not meet the definition of a housing unit at the time of followup, the address was eliminated and removed from the list for Person Interviewing. Still, those addresses were included in the estimate of errors of inclusion.

Address listing errors of omission affect the A.C.E. nonmatch rate and errors of inclusion affect the census erroneous enumeration rate.[6] The A.C.E. nonmatch rate is used to estimate the percentage of housing units missed by the census. The census erroneous enumeration rate is used to estimate the percentage of housing units erroneously enumerated in the census.[7]

[6] For more details, see Childers, 2001.

[7] For more details, see Barrett, et al, 2003.

Table 4. Address listing errors of inclusion and omission by ACERO

ACERO	Total A.C.E. housing units	Percent errors of inclusion	Number of confirmed A.C.E. and census housing units	Percent errors of omission
Boston	53,401	4.8	53,165	4.4
New York	68,189	3.5	69,115	4.8
Philadelphia	62,402	5.2	63,012	6.3
Detroit	56,041	4.3	54,749	2.1
Chicago	49,988	3.1	49,266	1.7
Kansas City	51,576	4.1	50,986	3.1
Seattle	68,215	4.2	67,794	3.7
Charlotte	88,470	5.0	86,353	2.9
Atlanta	99,932	6.9	96,201	3.5
Dallas	76,700	5.1	77,475	6.2
Denver	77,001	6.6	73,900	3.0
Los Angeles	86,512	5.0	85,484	3.9
Total	**838,427**	**5.0**	**827,500**	**3.9**

Table 4, Address listing errors of inclusion and omission by ACERO, shows the ACERO's percentage of housing units that were erroneously omitted from the A.C.E. listing (errors of omission) and the percentage of housing units that were erroneously included in the A.C.E. listing (errors of inclusion.)

- Overall, 5.0 percent of the housing units were erroneously included during Address Listing.

- Listers omitted 3.9 percent of housing units during Address Listing.

When we look at the results of the individual ACEROs, we find that:

- Atlanta (6.9 percent) and Denver (6.6 percent) had the highest percentage of errors of inclusion,

- Philadelphia (6.3 percent) and Dallas (6.2 percent) had the highest percentage of errors of omission,

- Chicago had the lowest percentage of errors of omission (1.7 percent) and the lowest percentage of errors of inclusion (3.1 percent.)

Tables 5A through 5C provide information for only mailout/mailback and update/leave areas. Address listing was conducted in mailout/mailback, update/leave and list/enumerate areas. However, there were only 5,918 housing units which were listed in the list/enumerate areas and they did not go through Initial Housing Unit matching. We did not calculate errors of inclusion or omission for these housing units.

Table 5A. Errors of inclusion and omission by Type of Enumeration Area (TEA)

Type of enumeration area	Total A.C.E. housing units	Percent errors of inclusion	Number of confirmed A.C.E. and census housing units	Percent errors of omission
Mailout/mailback	698,984	4.6	692,785	3.8
Update/leave	139,443	7.0	134,715	4.2
Total	**838,427**	**5.0**	**827,500**	**3.9**

Table 5A, Errors of inclusion and omission by Type of Enumeration Area (TEA), shows that the percent of errors of inclusion and omission was much higher in update/leave areas than for mailout/mailback areas.

Table 5B. Errors of inclusion by Type of Enumeration Area for each ACERO

		TEA			
		Mailout/mailback		Update/leave	
ACERO	Total housing unit	Housing units	Percent	Housing units	Percent
Boston	53,401	43,496	4.7	9,905	5.2
New York	68,189	67,693	3.4	496	6.3
Philadelphia	62,402	55,596	4.6	6,806	10.0
Detroit	56,041	47,583	4.3	8,458	4.3
Chicago	49,988	47,829	3.1	2,159	3.8
Kansas City	51,576	37,131	3.6	14,445	5.4
Seattle	68,215	61,597	4.0	6,618	6.7
Charlotte	88,470	65,237	4.4	23,233	6.8
Atlanta	99,932	86,279	7.1	13,653	5.6
Dallas	76,700	60,943	4.8	15,757	6.5
Denver	77,001	44,136	4.3	32,865	9.7
Los Angeles	86,512	81,464	4.9	5,048	6.0
Total	**838,427**	**698,984**	**4.6**	**139,443**	**7.0**

Table 5B, Errors of inclusion by Type of Enumeration Area for each ACERO, shows that:

- Philadelphia (10.0 percent) and Denver (9.7 percent) had the highest errors of inclusion in update/leave areas.

- Atlanta had the highest percent of errors of inclusion (7.1 percent) in mailout/mailback areas.

- Chicago had the lowest percent in errors of inclusion in update/leave areas (3.8 percent) and in mailout/mailback areas (3.1 percent.)

Table 5C. Errors of omission by Type of Enumeration Area for each ACERO

		TEA			
		Mailout/mailback		Update/leave	
ACERO	Total housing unit	Housing units	Percent	Housing units	Percent
Boston	53,165	43,396	4.5	9,769	4.0
New York	69,115	68,611	4.8	504	7.9
Philadelphia	63,012	56,765	6.7	6,247	2.4
Detroit	54,749	46,433	1.9	8,316	3.0
Chicago	49,266	47,152	1.7	2,114	1.8
Kansas City	50,986	37,113	3.6	13,873	1.7
Seattle	67,794	61,343	3.6	6,451	5.0
Charlotte	86,353	64,025	2.7	22,328	3.7
Atlanta	96,201	82,797	3.4	13,404	4.1
Dallas	77,475	61,682	6.0	15,793	6.9
Denver	73,900	43,467	2.9	30,433	3.2
Los Angeles	85,484	80,001	3.3	5,483	13.6
Total	**827,500**	**692,785**	**3.8**	**134,715**	**4.2**

Table 5C, Errors of omission by Type of Enumeration Area for each ACERO, shows that:

- Los Angeles (13.6 percent) and New York (7.9 percent) had the highest errors of omission in update/leave areas. Kansas City (1.7 percent) and Detroit (1.9 percent) had the lowest errors of omission in update/leave areas.

- Philadelphia had the highest percent of errors of omission (6.7 percent) in mailout/mailback areas and Chicago (1.7 percent) had the lowest.

4.2 Initial Housing Unit Followup Operation

Of the housing units that went to initial HUFU, how many were placed on the Preliminary Enhanced List?

The A.C.E. and census housing units confirmed to exist and those remaining unresolved after the followup matching operation were placed on the Preliminary Enhanced list. The HUFU rates were based on the number of housing units that went to followup.

Table 6. Number of addresses in Initial Housing Unit Followup (HUFU) and the HUFU rate

Housing units results*	Total followup		A.C.E. addresses		Census addresses	
	Number	Percent	Number	Percent	Number	Percent
Addresses that went to Followup	358,741	100.0	168,931	100.0	189,810	100.0
Confirmed to exist	211,495	59.0	127,741	75.6	83,754	44.1
Unresolved	2,054	0.6	1,065	0.6	989	0.5
HUFU Rate		**59.5**		**76.3**		**44.7**

* Results include nonmatched and matched A.C.E. and census addresses. Matches that went to followup were A.C.E. and census matches that were possible duplicates and A.C.E. matches with an undetermined unit status such as new construction, future construction, unfit for inhabitation, vacant trailer site, and so forth.

Table 6, Number of addresses in Initial Housing Unit Followup (HUFU) and the HUFU rate, shows the number of A.C.E. sample addresses and census addresses that went to followup and the number of addresses confirmed to exist as housing units or that remained unresolved. Results from Table 6 indicate that:

Of the 838,427 A.C.E. sample addresses and 859,296 census addresses in the same sample blocks, 358,741 addresses went to followup. These were A.C.E. addresses that could not be matched to census addresses, census addresses that could not be matched to A.C.E. addresses, matched addresses that were possible duplicates and A.C.E matches with an undetermined unit status such as new construction, future construction, unfit for inhabitation, vacant trailer site, and so forth.

- The overall HUFU rate was 59.5 percent, that is about 60 percent of the housing units that went to followup were placed on the Preliminary Enhanced List. Both confirmed and unresolved addresses were placed on the Preliminary Enhanced List.

- Of the addresses that went to followup, 59.0 percent (that is, 211,495 addresses) were confirmed to exist as housing units and 0.6 percent (that is, 2,054 addresses) were unresolved. Unresolved addresses did not have sufficient information on the followup form to determine whether the address was for an existing housing unit. Unresolved addresses placed on the Preliminary Enhanced List went to Person Interviewing for another opportunity for field staff to resolve the housing unit status.

- Although slightly more census addresses went to followup, the HUFU rate was much higher for A.C.E. addresses. Of the A.C.E. addresses that went to followup, 76.3 percent were placed on the Preliminary Enhanced List compared to 44.7 percent of the census addresses that went to followup.

4.3 Relisting Operation

How effective was the relisting operation in identifying A.C.E. housing units?

At the completion of the Initial Housing Unit After Followup Matching operation, if a large proportion (80 percent or more) of the A.C.E. housing units in a cluster was coded as a geocoding error, the cluster was flagged for the relisting operation. During the relisting operation, a different field lister visited the specified cluster with a blank Independent Listing Book and conducted the independent listing. These newly listed clusters did not go through the Initial Housing Unit Matching and Followup operations because those operations were completed before the relisting operation. Instead, the relisted clusters were matched for the first time in the Final Housing Unit Matching and Followup operations.

Table 7. Number of clusters relisted and the A.C.E. match rates

	Clusters		A.C.E.
	Number	Percent	Match Rate
Address Listing	11,303	100.0	94.3
Relisted	62	0.6	88.3

Table 7 provides the number of clusters relisted and compares the relisted clusters match rate to the overall A.C.E. match rate. To calculate the match rate for these relisted clusters, we divided the number of A.C.E. relisted housing units matched to the census in relisted clusters by the total number of A.C.E. housing units confirmed to exist in the relisted clusters. Results indicate that:

- There were 62 clusters identified for relisting. This represents less than one percent of all the clusters in Address Listing. After all the processing, we confirmed that all but one of the housing units originally listed in the 62 clusters were geocoding errors.

- The overall match rate for the relisted clusters was 88.3 percent. This percent was lower than the overall A.C.E. match rate of 94.3 percent. Relisted clusters tended to be the most difficult for the A.C.E. listers to locate, thus they originally listed housing units in the wrong block cluster. This lower match rate is not surprising since Census operations and/or census field staff also may have had difficulty geocoding the housing units in these same areas. Census geocoding error may be a reason for the lower match rate in relisted clusters.

4.4 Targeted Extended Search 2 (TES2) Operation

Were any erroneous enumerations in the Initial Housing Unit Matching identified as geocoding errors in the TES2 operation?

Census addresses coded as not existing as a housing unit (that is nonresidential or nonexistent on Census Day) within the cluster were classified as erroneous enumerations. There were concerns that some of these housing units existed outside the cluster and should have been coded as geocoding errors. To check this, we sent a sample of cases to the TES2 operation.

There were 5,364 housing units coded as erroneous enumerations that were in sample for the TES2 operation. Table 8, Targeted Extended Search 2 final codes, shows the number of census erroneous enumerations in the TES2 sample that were actually geocoding errors. That is, the final code was changed because the housing unit was found in the surrounding block (that is, GS) or beyond the ring of surrounding blocks (that is, GE.)

Table 8. Targeted Extended Search 2 final codes

Final code	Number	Percent
CE (Correctly enumerated)	145	2.7
DE (Census duplicate)	82	1.5
EE (Erroneously enumerated)	2,790	52.0
GC (Geocoded in the Block Cluster)	1,171	21.8
GE (Beyond the ring of surrounding blocks)	**103**	**1.9**
GS (In the surrounding blocks)	**340**	**6.3**
GU (unresolved)	21	0.4
M (A.C.E. and census match)	681	12.7
P (A.C.E. and census possible match)	1	<0.1
UE (unresolved)	30	0.6
Total	**5,364**	**100.0**

Results from Table 8, Targeted Extended Search 2 final codes, show that 8.2 percent (that is 443 housing units) of the 5,364 erroneous enumerations in the TES2 sample were geocoding errors.

Of the 443 housing units, 6.3 percent were found in the first ring of surrounding blocks and 1.9 percent were found beyond the ring of surrounding blocks.

4.5 Initial Housing Unit and Final Housing Unit Followup Questions

During the followup operations, we asked the interviewers to determine if there were any matches or duplicates to the followup addresses from the list of addresses in the cluster. When enumerators misunderstood the questions, they referred to the same housing unit listed on the followup form (as a match or duplicate), instead of finding another listing. Table 9 shows the percentage of forms for which enumerators incorrectly answered the duplicate and match questions on the initial or final HUFU forms.

Table 9. Errors in answering the duplicate and match questions on the followup forms

Phase	Percent of Forms with Incorrect Answers for the Duplicate Questions	Percent of Forms with Incorrect Answers for the Match Questions
Initial HUFU	14.2	0.8
Final HUFU	0.6	0.2

The purpose of the duplicate and match questions was to determine if there were more duplicates or a match to another listing of the address, in the specific column of the Housing Unit Reference List (that is, a listing other than the followup address(es) listed on the top of the form.)

As seen in Table 9, there was a substantial difference between the error rate during the Initial HUFU and the Final HUFU for the duplicate question. The difference was not as great for the match question. Due to interviewers' widespread misinterpretations of the duplicate question during the Initial Housing Unit Followup operation, clarification of the question for the Final Housing Unit Followup operation was required. The improvement in these answers, while likely due to the wording changes and the addition of the alternative wording printed on the questionnaire, may also be affected by the acquired experience of the interviewers. Their deeper understanding of the intent of the A.C.E. operation, as well as increased attention to these specific questions during the Final Housing Unit operation training may have contributed to the large decrease in the error rates. While this analysis cannot separate out the individual effects of each of these differences, the combined effect resulted in the substantial improvement observed.

5. CONCLUSIONS/RECOMMENDATIONS

The housing unit field operations and instruments evaluated in this paper for the Accuracy and Coverage Evaluation were appropriate in measuring coverage of housing units. We make the following recommendations:

- Address Listing operation

  The Address Listing operation was an independent listing of addresses for housing units in the Accuracy and Coverage Evaluation sample block clusters. This type of independent listing is a very difficult and error prone task. The quality assurance process for Address Listing worked effectively to identify, prevent and correct errors as necessary. The field rework resulting from the quality assurance checks resulted in improved listing of 18.9 percent of the clusters. Therefore, we recommend continuing the quality assurance process on Address Listing.

Less than one percent of the clusters in the Accuracy and Coverage Evaluation (62 clusters out of 11,303) had to be relisted. As a result of the Relisting operation, we were able to match about 88.3 percent of the housing units in the relist clusters to the census inventory. Therefore, we recommend that relisting continue to be part of future coverage measurement operations.

- Initial Housing Unit Followup operation

  The Initial Housing Unit Followup operation confirmed that more than half of the addresses that went to followup (59.0 percent) existed as housing units and were placed on the Preliminary Enhanced List. Also, using final matching results from the Initial Housing Unit operation we estimated that about 5 percent of the housing units were erroneously listed and less than 4 percent of the addresses were missed during Address Listing. We recommend that housing unit matching and followup continue to be part of future coverage measurement operations.

  The second Targeted Extended Search operation provided evidence that there were some housing units classified as erroneous enumerations that were actually geocoding errors. We recommend that we build the second Targeted Extended Search operation into the Initial Housing Unit Followup operation to minimize misclassification of geocoding errors as erroneous enumerations.

- Followup Questionnaire

  Results from comparisons of Initial and Final Housing Unit Followup interviewer response patterns verified suspicions that some questions were not being understood by the interviewers during the initial phase. There was a substantial decrease in the percentage of questionnaires with incorrect answers in the duplicate questions during the Final Housing Unit Followup (0.6 percent) than during the Initial Housing Unit Followup (14.2 percent). The decrease in the error rate was not as great for the match questions (from 0.8 percent in the initial phase to 0.2 percent in the final phase). We recommend that for future applications we give as much testing attention to the interviewer's instruments as we do to the instruments used by respondents, in particular, we should conduct cognitive testing on future followup instruments.

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Appendix A

Formulas used:

$$\text{Error of inclusion} = \frac{DIs + GIs + ZIs + ZMs}{Ms + Ps + MUs + CIs + NIs + UIs + DIs + GIs + ZIs + ZMs.}$$

$$\text{Error of omission} = \frac{NEs + CEs}{Ms + Ps + NIs + NEs + CIs + CEs}$$

$$\text{HUFU Rate} = \frac{Ms + CIs + CEs + MUs + UIs + UEs}{\text{Total HUs that went to FU}}$$

$$\text{Relist Match Rate} = \frac{Ms + MUs}{Ms + MUs + CIs + UIs}$$

See Appendix B for the definition of each variable (match codes.)

Appendix B

HU and FHU Match Codes and Definitions

Following are the match codes and definitions used in the Housing Unit operations by the A.C.E. clerical matchers.

M The P-sample and census addresses match.

MU The A.C.E. and census addresses match and there is not enough information on the followup form to confirm this match as a housing unit with certainty. The followup interview was either not done, was incomplete, was never sent, had contradictory information, or was a non-interview. The match status is matched, but the housing unit status is unresolved.

P The P-sample and census housing units are possible matches. There was either no information from followup or not enough information to assign a match with confidence.

UI There is not enough information on the followup form to assign a code to the nonmatched P-sample housing unit with certainty. The followup interview was either not done, was incomplete, was never sent, had contradictory information, or was a non-interview.

CI The A.C.E. housing unit existed as a housing unit on Census Day and is correctly geocoded in the block cluster. The housing unit is not found in the census.

ZI The A.C.E. address is incorrectly included in the A.C.E. list of housing units. The code is used when the P-sample address did not refer to a housing unit at the time of the followup interview (for example housing unit burned, mobile home moved, address is commercial property or a special place.)

ZM The map spot number associated with a housing unit is in error. This code removes the housing unit from the P-sample.

DI The P-sample housing unit is a duplicate of another P-sample housing unit.

GI The A.C.E. housing unit existed as a housing unit on Census Day, but is incorrectly listed in the block cluster. The housing unit is an A.C.E. geocoding error.

NI The P-sample address is a nonmatch to a census address.

NE The census address in the E-sample is a nonmatch to an A.C.E. address.

UE There is not enough information on the followup form to assign a code to the E-sample nonmatched housing unit with certainty. The followup interview was either not done, was incomplete, was never sent, had contradictory information, or was a non-interview.

CE The E-sample housing unit existed as a housing unit on Census Day and is correctly geocoded in the block cluster. The housing unit was not found in the P-sample.

EE The census housing unit is erroneously listed on the HCUF, because the address is not a housing unit in the block cluster on Census Day (for example, the housing unit burned, the mobile home moved, the address is commercial property or a special place, or the address is nonexistent within the block cluster.)

DE The census housing unit is a duplicate of another census address and is erroneously enumerated in the HCUF.

GE The E-sample housing unit existed as a housing unit on Census Day, but was incorrectly geocoded to the block cluster. The housing unit is erroneously enumerated in this block cluster because of a geocoding error.

GS The E-sample housing unit was found to be in the surrounding blocks during the targeted extended search field followup. The E-sample housing unit was counted once and only once in the expanded search area and is correctly enumerated within the expanded search area.

GC The E-sample housing unit was found in the block cluster during the targeted extended search field followup. It is correctly enumerated in the block cluster.

GU The E-sample housing unit is not located in the A.C.E. block cluster, and there was not enough information to determine if it were in the surrounding block. The TES field followup interview was either not done, was incomplete, had contradictory information, or was a noninterview.